

Oil Content Analysis of Sunflower By Nuclear Magnetic Resonance, Solvent Extraction, and Near-Infrared Reflectance: A Cost Study

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SUMMARY

Cost estimates indicate that using nuclear magnetic resonance (NMR) and near-infrared reflectance (NIR) 1/ instruments to measure oil content of sunflower is both practical and advantageous over solvent extraction (SE) procedures in most cases. Operating procedures for both the NMR and NIR are simple and there is no use of hazardous solvents as required by SE. Previous studies have shown a high positive correlation between NMR and SE determinations.

Per-sample operating costs for the NMR are estimated at three different levels of operation: 12, 120, and 400 samples per 8-hour day. For the SE method, per-sample costs are estimated for just two levels of operation, 12 and 120 samples per 8-hour day. Cost estimates for firms who recondense the solvent in the SE procedure at the 120-per day operation are also provided. NIR per sample costs are figured at 120 samples per 8-hour day.

Investment costs for the NMR are \$18,771.15, compared to \$6,080.31 for the twelve unit SE, \$16,553.63 for the 120-SE unit, and \$12,540.00 for the NIR unit. Though the initial investment cost of the NMR and NIR is high, per-sample costs for both are usually lower than SE sample costs. At the 120 sample per day rate the cost per sample for NMR is \$0.73 and \$0.83 for the NIR compared to \$2.21 per sample for SE. In addition to the cost advantage, the NMR and NIR methods can process substantially more samples with fewer employees, require less space, and have fewer safety hazards.

Fixed costs are assumed to be constant at all sample levels for both NMR, SE, and NIR; thus they decline in percentage of total costs as the number of samples analyzed increases. Total variable costs for the NMR increase primarily because of increased labor costs. Variable cost increases for SE result from increased labor, utility, and supply costs associated with higher numbers of samples analyzed. Laboratories presently operating SE equipment may find that for small numbers of samples the cost of conversion to NMR or NIR is not advantageous.

1/NIR is presented for comparison purposes. At the time this report was prepared, the procedure for grinding sunflower samples for NIR analysis was not satisfactory. It should still be considered an experimental procedure.

OIL CONTENT ANALYSIS OF SUNFLOWER
BY NUCLEAR MAGNETIC RESONANCE, SOLVENT EXTRACTION,
AND NEAR-INFRARED REFLECTANCE: A COST STUDY

By Paul E. Parker and Floyd F. Niernberger*

INTRODUCTION

Oilseed sunflower acreage has increased substantially since 1976, with the introduction of high yielding hybrid varieties. With increased availability of sunflower supply, foreign demand has increased and the development of a domestic market has progressed beyond the market testing stage. Agronomic research emphasis has centered on high yields, disease resistance and oil content. Oil has been and remains the most valuable constituent, though markets are being developed for the meal. Present U.S. manufacturing procedures result in meal with high fiber content which limits its usefulness. Newly planned processing facilities are incorporating changes which will increase protein and lower the fiber portions of resulting meal. Even with these refinements, meal will remain a by-product of the oil extraction process (11). 2/

Sunflower contracts often pay premiums on the basis of oil content (4); thus efficient, accurate methods of determination are required for the orderly marketing of oilseed sunflower. This report gives estimates of investment and operating costs of using nuclear magnetic resonance (NMR), solvent extraction (SE), and near-infrared reflectance (NIR) procedures to determine oil content of sunflower. Annual cost schedules of per-sample analysis are presented for three levels of operation for the NMR, two levels for SE, and one level for the NIR.

The Federal Grain Inspection Service (FGIS) is in the process of evaluating the need for federal standards for sunflower. If standards are developed, oil should be considered as a factor for determining sunflower quality. The information contained in this study will be useful in determining the feasibility and cost of various methods of oil determinations.

This report should also provide useful guidelines for anyone in the grain industry considering investment in oil determination apparatus. Grain producers, handlers, merchandisers, and laboratories concerned with oil content testing can use this information to plan improvement of their specific operations and their profit.

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2/ Underscored numbers in parentheses refer to references listed at the end of this report.

Since the 1880's the standard method of oil determinations for oilseeds has been solvent extraction (SE), a time-consuming analytical procedure (7). The approved method of the American Oil Chemists' Society (AOCS) for SE (2, 3) requires analytical expertise in weighing, uniform grinding of the sample, and extraction in heated solvent for 6 hours. The extraction process is performed in a Butt percolator-type apparatus using petroleum ether as the solvent. The extracted oil is weighed and expressed as a percentage of the weight of oilseed used in the procedure.

During the 1960's, a non-destructive method of oil determination, nuclear magnetic resonance (NMR), became available (7). NMR allows accurate measurements of oil without the need for grinding and extraction. Results on dried samples can be obtained in as few as 32 to 128 seconds, depending on the degree of accuracy required (Methodology for NMR, NIR and SE are compared in table 1). However, the sample must be dried for at least 3 hours before oil content can be analyzed. The NMR value is related to the total hydrogen proton content of the liquid fraction of the seed, independent of the hydrogen protons in the non-liquid fraction (12). Within the liquid fraction, the NMR signal cannot differentiate between hydrogen protons of water and oil. Moisture contents over 4.5 percent tend to give an additive effect to the oil reading. Drying the seed for 3 hours at 103°C or for 24 hours at 60°C, lowers moisture content below the point of interference (8).

In comparison studies between SE and the NMR, Conway (5) observed a high correlation between results of the two methods. Findings by Alexander, *et al.* (1) supported a high positive correlation between NMR determinations and the standard SE method. Fehr, *et al.* (6) found that the reproducibility of results for SE was 0.7 while for NMR it was 0.3 percent. The poorer showing for SE was attributed to higher operator variability. Fehr, *et al.* concluded that the NMR was superior to SE for rapid, accurate, non-destructive measurement of oil content.

Research investigations into procedures and techniques for developing near-infrared reflectance (NIR) spectrophotometry to determine the quality constituents of agricultural products have been carried out since the sixties. A review of these investigations and a description of NIR instruments used for determination of protein, oil and moisture in certain grains and oilseeds have been made (14).

Currently the AOCS has not published an approved method for oil determination by NIR instruments. Oilseed analysis methods by NIR in most cases requires samples to be ground. Difficulties in uniform particle size grinding for soybeans have been reported (13). Long grinding times, plugged screens and difficulty in cleaning of grinders used for grinding oilseed samples prior to analysis by NIR have also been reported.

A recent survey of the use of near-infrared techniques reported that most of the interest centered around the determination of protein, moisture and oil (9). Of the 232 respondents from around the world, 49 reported they currently were using an NIR instrument for oil content

measurement. Thirty-three respondents indicated they were using the NIR for analyzing soybeans and meal and 12 showed sunflower seed. Mention was also made of NIR use for flax and rapeseed.

Research results from use of NIR instruments for measurement of oil content of sunflower do not appear in the literature. The NIR committee of the American Association of Cereal Chemists (AACC) has discussed a collaborative research project on oil content measurement of sunflower by NIR instruments, but to date the study has not been completed. Difficulty in standardization of a grinding procedure for sample preparation was cited as reason for the delay.

It would be unwise to speculate when a method for sunflower oil determination by NIR techniques will be developed, tested and approved for use by the AOCS, AACC or FGIS. However, the reader may be interested in an estimated cost schedule for NIR analysis to use for comparison with NMR and SE costs provided in the text. Costs for NIR oil analyses for sunflower were developed using information contained in a recent NIR cost study for protein and moisture measurement (10).

METHODOLOGY

The economic-engineering approach is used to develop cost estimates for three usage levels of the NMR, two usage levels for SE and 1 level for the NIR in determining oil content of sunflower. The approach required determining input needs (equipment, space, and labor) and output results (samples performed per time period) for development of cost relationships at several levels, and methods of operation. Costs determined in this manner are termed synthetic; they do not reflect costs actually experienced in any firm's or individual's operations, but represent a synthesis of operations observed in a number of cases. The costs are contingent upon assumptions and specifications used in setting up the study.

The cost analyses in this study are based on an average daily number of samples analyzed during a single 8-hour shift. Workloads and operator performance may fluctuate greatly throughout the year; consequently, annual sample capacity for each category also should be considered. The annual sample capacity is based on 260 operating days per year. This number of operating days was selected because it is felt that Saturday and Sunday operation of oilseed industry firms at peak handling periods probably equal weekday shutdowns due to holidays during the year.

Due to the fixed requirements of SE (the number of samples which can be run is limited to the number of extractors) two daily sample rates were used for this study; 12 per 8-hour day and 120 per 8-hour day. Both NMR and NIR are more flexible in the number of samples which can be processed. These rates correspond to small and large laboratory setups presently in use. In order to provide a clear comparison between NMR and SE the same

sample rates were used for the NMR. A 400 sample per 8-hour day rate was also included to show the potential flexibility of the NMR. A sample rate of 120 per 8-hour day as used for the NIR to facilitate comparisons with NMR and SE. Twelve samples per day equal 3,120 samples annually; 120 samples per day, 31,200; and 400 samples per day, 104,000. The operator or operators would have the usual rest periods and other nonoperating times experienced in actual operation. The time allowed for analysis includes grinding, drying, weighing, extraction, and cooling, depending on the method. A specific breakdown for each operation was not obtained. Recording data on necessary forms, cleaning up, sample disposal, and the general maintenance of equipment and premises also is included in the sample-rate estimates.

The rate of samples analyzed per shift in this study does not include labor and time in obtaining the sunflower sample to be tested. Estimates of labor and time for sampling different containers, vehicles, storage facilities, and processes are believed too variable to be meaningful. Thus, it is assumed that samples of sunflower are located within a short distance of the analysis area and are easily accessible to the operator. This assumption would be logical for most laboratory operations; however, users at isolated locations or processes should be cautioned that if the operator also must physically take the sample from the lot to be analyzed, a lower rate of sample analyses per day should be expected.

Practices applicable to an individual firm may not be covered by this study since it is designed to provide general information on a limited number of costs. In such instances, equipment manufacturers and engineering firms may be consulted to provide estimates for a specific operation.

COSTS

Costs are classified as investment and operating, with the latter further classified as fixed and variable. Investment and operating costs are representative of the Minneapolis, Minn. area as of May 1, 1979. Costs for other locations may vary from this reference site and should be determined for each application. Fixed costs include depreciation, interest on investment, space assessment, training expenses, taxes, and insurance. Variable costs include operator wages, maintenance, repairs, supply costs, calibration tests, and utilities.

Investment Costs

Initial investment costs for the NMR method includes the NMR unit and associated equipment. Since there is only one manufacturer of the NMR, this cost should be constant except for shipping costs. Costs of the other required accessories will vary depending on the supplier. For this study a laboratory environment was considered essential due to the sensitive nature of the NMR unit. Alterations to existing laboratory facilities should be minimum as only 110 volt outlets for the NMR unit and drying ovens are required.

The magnet contained within the NMR unit does need to be isolated from metal beams, pipes and other ferrous structures. This may require some planning when placing the unit in the laboratory. It is assumed that under most laboratory conditions, equipment can be connected directly into existing electrical facilities with little, if any, alterations.

Initial investment costs for the SE method varies depending on the source of supply. Numerous concerns manufacture the equipment and the cost may vary somewhat. Because of the solvent hazard, a laboratory facility equipped with fume hoods is considered essential. Alterations to laboratories not equipped with fume hoods could be extensive, especially with a large number of extraction units. Electrical and plumbing requirements would also be dependent on the size of the operation and existing facilities. Small operations could be set up with a minimum of alterations while large operations may require extensive adjustments in facilities. The 12-unit setup cost is modeled after a small laboratory which follows standard AOCS equipment specifications. Cost estimates for the 120-unit setup are based on modifications of the AOCS equipment specifications and procedures. The main point of difference between the 12-unit and the 120-unit extraction setups is the substitution of a pickle flask for the standard AOCS butt type tube and soxhlet flask. This modification requires considerably less solvent, and several extraction units can be heated on the same heating unit. Standard AOCS equipment specifications for the 120-unit setup would result in higher investment cost and operating costs than shown in this study.

Initial investment costs include the NIR instrument itself, associated equipment, and installation costs. Equipment costs vary by manufacturer, model, and recommended accessories (see table 2). Installation costs vary with the facility and the location within the facility where the equipment is installed. A major factor influencing installation costs is whether a controlled-environment for the NIR equipment already exists in the proposed location. Installation in quality-assurance laboratories may require no more than clearing an existing table or setting up an instrument bench and plugging the sample grinder and NIR instrument into electrical receptacles. Nonlaboratory locations can necessitate installing electrical circuits and voltage regulator; closing in the analysis area; and providing noise, dust, and temperature control equipment (in general, providing satisfactory equipment and operator conditions for accurate sample preparation and analysis).

Tables 3, 4 and 5 represent investment costs for NMR, SE and NIR methodologies.

Operating Costs

Operating cost estimates are shown in Tables 6 and 7. They do not include costs of obtaining the sunflower or costs of preparing forms, and keeping information transcribed by the operator.

Fixed Costs

Depreciation on the initial investment in equipment, including installation, is spread over the estimated productive life of the equipment and makes up the major portion of the fixed costs. Other costs that do not vary with output are interest on investment, space assessment, training expenses, taxes, and insurance.

Depreciation -- Equipment costs, including installation and electrical connections, are depreciated at an annual rate of 20 percent over a 5-year period. The service life of NMR and NIR instruments is difficult to estimate, because of the rapid technological advances since their commercial introduction, and because the relatively recent introduction precludes sufficient life expectancy information. Table 7 depicts total cost and cost per sample for depreciation rates of from 5-10 years.

Interest on investment -- Interest is calculated at 11 percent of 1/2 the initial equipment cost, including installation expense.

Space assessment -- Space estimates of 90 square feet for the NMR method, 80 square feet for the 12-unit SE, 150 square feet for the 120-unit SE process, and 60 square feet for the NIR are needed for satisfactory operation of the analysis equipment. Space costs are based on the rate of \$10 per square feet.

Training expenses -- The methodology of the NMR and NIR is uncomplicated. Training sessions or seminars have not been considered necessary. For the purposes of this study, training will consist of supervised operation of the NMR and NIR equipment by the trainee for a period of 3 days.

Training expenses for SE are calculated at 5 days of supervised operation of the extraction apparatus by a qualified technician.

Training of supervisors is assessed at the rate of 4 additional hours.

Taxes and insurance -- Taxes are based on 1 percent of the assessed value. Assessed value is calculated at the rate of 35 percent of the total initial investment cost. Insurance is estimated at 46.5 mills per \$1 of initial investment (.465 percent on 100 percent of the replacement cost).

Variable Costs

Variable costs in this estimate include such items as operator wages, maintenance and repairs, supply costs, calibration tests, and utilities that are a function of the number of samples analyzed. Wages paid to operators make up a large portion of variable costs and a major portion of total costs.

Operator wages -- The operator wage used in this study is based on an 8-hour day and varies according to the number of operators required and

their skill classification. Operator requirements used in this study include:

12 samples per day	NMR	1 laboratory technician
" " " "	SE	1 " "
120 samples per day	NMR	1 " "
" " " "	SE	3 " "
" " " "	NIR	1 " plus
		2 additional hours
400 samples per day	NMR	2 lab technicians

The wage rate for semiskilled laboratory personnel in Minneapolis is based on approximately \$7.29 per hour (\$6.08 + 20 percent fringe benefits). The wage rate for skilled laboratory personnel (chemist) in Minneapolis is based on approximately \$8.21 per hour (\$6.84 + 20 percent fringe benefits). The skilled wage rate is only used in calculating supervisor training costs. Local wage rates may be higher or lower for a particular firm. Annual wages are based on 260 days of operation, and the assumption is made that the operator would need replacement for vacation or sickness for 15 days. The 12 samples per 8-hour day for NMR and SE estimates assume the use of employees from other jobs at no additional labor charge to cover vacation and sickness days. Wage cost estimates for 120 samples or more per 8-hour day for both NMR, SE and NIR include replacement personnel wages for the additional 15 days per employee.

For the 120 samples per 8-hour-day NIR estimates, an additional semiskilled employee would be required to assist for 2 hours. This employee is expected to be used on other laboratory duties the remainder of the shift, and thus labor costs for the remaining 6 hours would be assigned to other laboratory functions.

Maintenance and repairs -- The cost of maintenance and repairs is estimated at 1 percent of the purchase cost of the equipment for the NMR, SE and NIR methods.

NMR technology is relatively new, and reliable data concerning maintenance and repairs is minimal. The newest NMR models, Mark III and Mark IIIA, are constructed of plug-in solid state circuit boards. This feature should reduce the possibility of equipment failure and facilitate component replacement in the event of failure.

Maintenance and repair costs for SE are included to compensate for normal breakage of extractors.

Supply costs -- The NMR does not require supplies other than desiccant. Oil determinations are made on whole dried seed with no

veral different items for the extraction is petroleum ether. The standard AOCS requires approximately 200 ml of solvent Flask method used in 120-unit setup

consumes 45 ml of solvent per sample. By recondensing the solvent, up to 66 percent can be saved. Not all laboratories recondense the ether so figures for both are presented in table 8. Equal amounts, by weight (50 g) of seed and a grinding additive (diatomaceous earth) are ground for each sample. The ground mixture is folded between two pieces of filter paper to prevent the escape of meal during extraction. Supply costs on a cost per sample basis are presented in table 8.

The coffee-type grinders proposed for use in grinding sunflower samples for NIR analysis are inexpensive and wear out quickly. (Difficulty in grinding sunflower samples was previously discussed.) A purchase of five grinders is proposed for initial investment, it is then estimated that two grinders will be required annually as replacements for the 80 samples per 8-hour shift usage level.

In the grinding of sunflower samples it is currently recommended by one NIR manufacturer that equal amounts (25 g) of sunflower and a grinding additive (calcium carbonate) be used. It is estimated that 30 grams (25 usage + 5 loss in storage and preparation) of calcium carbonate will be required per sample at a price of \$1 per pound.

Calibration -- The standard procedure for calibration of an NMR unit is to place sealed sample tubes containing oilseed of a known oil content into the unit. The NMR readout is then adjusted until the reading corresponds to the oil content of the sample. Some laboratories make up their own calibration standards and determine oil contents of the calibration sample by the standard AOCS extraction method. Under normal laboratory conditions the NMR units are calibrated periodically throughout the daily operation of the unit. Time required for calibration is approximately the same time as required for a normal sample determination. Annual calibration cost is estimated at the cost of performing 25 outside laboratory SE determinations, at the rate of \$5 per sample. Costs for samples analyzed by in-house facilities could be expected to result in lower calibration costs.

Since the SE method is the standard AOCS method, calibration testing is not considered necessary for the purposes of this study.

Manufacturers and users agree that after initial calibration, following setup, NIR instrument analyses should be monitored through: (1) check samples from a service laboratory, (2) by duplicate sample testing using the standard AOCS solvent extraction method, or (3) by daily monitoring of sealed cells of known oil values. The frequency of testing would, of course, vary with the firm's type of activity, economic implications of testing error, and number of samples analyzed annually. It is estimated that minimum requirements would be 60- and 80-SE determinations annually, for the 80- and 120-sample per day operations, respectively. The charge was assumed to be at the current commercial laboratory rate of \$5 per-sample.

Utilities -- Water consumption for the SE method is based on the rate of 60 cents per 1,000 gallons. The NMR and NIR procedures do not require

any water for operation. The main water requirement for SE is cooling water for the extractor condensers. The rate is estimated at 0.5 gallons per condenser per minute of operation. Under normal operating conditions the cooling water is required for at least 6 hours per day.

Electrical costs for the NMR, SE and NIR methods are based on the rate of 4 cents per kilowatt hour (KWH). The NMR unit consumes 0.06 KWH and the drying oven 1.92 KWH. It is assumed that the NMR unit would be used for 8 hours and the oven for 3 hours. The main power consumers for the SE method are the heating units for the extractors. The 12-unit SE apparatus requires 1.2 KWH and the 120-unit, 8.4 KWH. Blowers contained in the fume hoods require .37 KWH per hood. Grinders use a minimum of power, estimated at 7.8 KWH/year for the 12-unit and 78 KWH/year for the 120-unit.

Manufacturers' instructions for most NIR instrument models recommend that the instrument be left on continuously. The estimated power consumption for the grinders is 78 KWH and 100 KWH annually, for the 80- and 120-sample per day operations respectively.

COST COMPARISONS

In this study, estimated per-sample costs are compared between NMR, SE, and NIR methods. Actual fees charged by commercial laboratories (\$4.50 - \$5) are lower than the 12-unit estimated cost for both NMR and SE. Cost differences may be due to lower fixed costs of established laboratories, also most laboratories run more than 12 samples per day allowing for a lower per-sample cost. At the 120-sample per day rate the estimated cost per sample for NMR, SE, and NIR is well below the commercial laboratory fee. Commercial laboratory fees would normally be expected to be higher to allow for return on the investment and to cover the risk of the business operation.

For small laboratories processing limited numbers of samples the SE methodology appears to be more economical than the NMR procedure. At 12 samples per day the cost per-sample for SE is \$6.81, while the NMR sample cost at the same level of operation is \$6.98. At levels of 13 or more samples per day the cost advantage is greater for the NMR procedure. In operations performing 120-samples per day the cost per sample for the NMR method decreases to \$0.73 compared to \$2.21 for the SE procedure. The NMR appears to be more cost efficient for laboratories in the process of being established and for laboratories handling more than 12 samples per day.

Rapid analysis, greater accuracy, small space needs, fewer personnel, simple methodology, and fewer safety hazards are among the additional advantages of NMR methodology. Cost advantages of NMR over already established SE laboratories will depend on the facilities and the number of samples analyzed per year.

Per-sample NIR cost estimates for oil content measurement of sunflower at the comparable 120-sample per 8-hour day level are considerably less

(\$0.83) than the SE method (\$2.21) and not much higher than the NMR (\$0.73).

One disadvantage of the NIR over the NMR at the 120-sample level is that more than one operator (2 additional hours) is estimated to be needed, which may not be feasible for some laboratory operations. It should be noted that the NMR operator would have time to do other assigned duties beside running the analyses as discussed in the assumptions on operator wages.

A second disadvantage is that sample preparation for NIR instrument analysis requires the sample be ground, while whole seeds can be used in NMR instrument analysis. The difficulties encountered to date of grinding sunflower samples consist of inadequate particle uniformity, low grinding capacity, addition of a grinding additive, and lack of standards for grinders or procedure.

The NIR has several apparent advantages over the NMR. One advantage is the flexibility of the NIR for other kinds of constituent analyses. Instrumentation of the NIR is such that moisture of the sunflower sample can be obtained from the same sample used for oil analyses, usually at no additional cost (subject to available calibration capacity of the NIR instrument). The protein of the sunflower sample may also be obtained at little additional cost, subject to research investigation and methods approval.

The second advantage would be in cost. The widespread use of the NIR for protein and moisture analysis of grain and oilseed samples by the industry and by FGIS would indicate that investment costs would not be required by those firms already operating NIR units. Depreciation and interest on investment of the NIR instrument make up about 12 percent of estimated annual operating costs for the 120-sample-per-shift operation. Elimination of these investment costs in the analyses would result in lower per-sample costs for the NIR.

The drying of sunflower samples for analyses by NMR is not needed in NIR operations. Thus, sample analysis use of the NIR for rapid unloading and binning of samples at receiving points is feasible where use of the NMR is not.

The cost comparison for the two systems would appear to favor the NIR method. However, grinding of the sample in the NIR process remains a problem which may not be promptly resolved.

Cost estimates indicate that using the NMR and NIR instruments to measure oil content of sunflower is both practical and advantageous over SE procedures in most cases. In comparing the NMR procedure with the NIR, the NMR offers advantages in the number of employees required and the

number of samples which can be processed per day. However, it does not offer the potential versatility that the NIR method offers. If the present difficulties of grinding sunflower are resolved, the use of the NIR instrument (for wheat protein determinations) could be expanded to provide valuable end use quality information for sunflower.

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Table 1 -- Oil determination procedures

Nuclear Magnetic Resonance (NMR)		Solvent Extraction (SE)		Near-Infrared Reflectance (NIR)	
Procedure	Required equipment	Procedure	Required equipment	Procedure	Required equipment
Sample is cleaned	Sieves - 8/64" 12/64" round holed	Sample is cleaned	Sieves - 8/64" 12/64" round holed	Sample is cleaned	Sieves - 8/64" 12/64" round holed
Sample is divided into smaller equal portions	Boerner divider	Sample is divided into smaller equal portions	Boerner divider	Sample is divided into smaller equal portions	Boerner divider
Weigh out approx. 75g. of cleaned seed	Balance	Weigh out approx. 50g. of seed and 50g. of diatomaceous earth	Balance	Weigh out approx. 25g. of cleaned seed. Add equal weight of calcium carbonate.	Balance
Weighed sample is dried for 3 hours	Forced-draft oven (Metal cans for sample)	Grind mixture	Grinder	Grind mixture	Grinder
Sample is cooled under desiccating conditions, 4 hrs	Desiccating cabinet (desiccating) net (desiccating) agent)	Weigh 4g. of ground mixture	Analytical balance	Pack ground mixture into sample cup of NIR	NIR (NIR sample cup)
Sample is placed in NMR for oil determination	NMR (NMR sample tube)	Extract with ether, 6 hrs.	Extraction apparatus	Sample is placed in NIR for oil determination	
		Evaporate ether and cool extracted sample	Desiccating cabinet (Desiccant)		
		Weigh extracted oil	Analytical balance		

Table 2 -- NIR instruments with oil measurement capabilities 1/

Vendor	Model	Cost
Technicon Industrial Systems Tarrytown, NY	InfraAnalyzer 2.5A	\$ 8,500
	" 200	10,000
	" 300	11,400
	" 400	17,000
Neotec Instruments Silver Springs, MD	GQA-21	\$ 8,200
	GQA-31	10,400
	GQA-41	18,250
	GQA-51	29,900
Dickey-John Corp. Auburn, IL	GAC III-660	\$ 9,410
	GAC III-760	12,680
	GAC III-780	13,990
International Stanley Co. Omaha, NE	Grain Analyzer	\$ 9,995

1/As of May 1, 1979. Does not include freight charges.

Table 3 -- Equipment and installation costs of the NMR instrument and accessories, 1979

Cost item	Equipment costs	Installation, electrical and setup costs	Total costs
		<u>Dollars</u>	
Direct:			
NMR instrument <u>1/</u>	15,500.00	30.00	15,530.00
Forced draft drying oven	730.00	30.00	760.00
Desiccating cabinet	184.00	--	184.00
Balance	795.00	--	795.00
Boerner divider	354.00	--	354.00
Sieves	22.00	--	22.00
Accessories	65.05	--	65.05
Taxes & freight	225.86	--	225.86
Total direct	17,875.91	60.00	17,935.91
	700.50	10.00	719.50
	00	--	84.00
	74	--	31.74
	24	10.00	835.24
Total	18,701.15	70.00	18,771.15

1/The only current supplier of NMR units is Newport of North America, Vellanova, PA
 -- = not applicable.

Table 4 -- Equipment and installation costs of SE apparatus and associated accessories, 1979

Cost item	12-unit setup			120-unit setup		
	Equipment costs	Installation, electrical, and setup costs	Total costs	Equipment costs	Installation, electrical, and setup costs	Total costs
<u>Dollars</u>						
Direct:						
Extraction apparatus	1,172.28	30.00	1,202.28	5,979.38	30.00	6,009.38
Grinder	30.00	--	30.00	300.00	--	300.00
Desiccating cabinet	184.00	--	184.00	368.00	--	368.00
Balances	1,240.00	--	1,240.00	1,240.00	--	1,240.00
Boerner divider	354.00	--	354.00	354.00	--	354.00
Sieves	22.00	--	22.00	22.00	--	22.00
Fume hoods & bases	2,160.00	117.00	2,277.00	6,480.00	350.00	6,830.00
Taxes & freight	181.75	--	181.75	563.39	--	563.39
Total direct	5,344.03	147.00	5,491.03	15,306.77	380.00	15,686.77
Indirect:						
Work tables	473.00	10.00	483.00	709.50	10.00	719.50
Chair	84.00	--	84.00	114.40	--	114.40
Taxes	22.28	--	22.28	32.96	--	32.96
Total indirect	579.28	10.00	589.28	856.86	10.00	866.86
Total	5,923.31	157.00	6,080.31	16,163.63	390.00	16,553.63

-- = not applicable.

Table 5 -- Equipment and installation costs of the NIR instrument and accessories, 1979

Cost item	Equipment costs	Installation, electrical and setup costs	Total costs
		Dollars	
NIR instrument <u>1/</u>	11,100	30	11,130
Sample grinder <u>2/</u>	150	--	150
Balance	50	--	50
Work tables	475	10	485
Chair	75	--	75
Accessories	100	--	100
Taxes & freight	550	--	550
Total	12,500	40	12,540

1/Average cost of mid-range instruments listed in Table 2, F.O.B. factory.

2/Five grinders at \$30 each.

-- = not applicable

Table 6--Estimated annual operating costs of NMR, SE, and NIR units, 1979 1/

Cost Item	Number of samples analyzed per 8-hour shift										
	NMR					SE					NIR
	12	120	400	120	120	120	120	120	120	120	
<u>Dollars</u>											
Fixed:											
Depreciation	3,754.23	3,754.23	3,754.23	1,216.06	3,310.73					2,508.00	
Interest on investment	1,032.41	1,032.41	1,032.41	334.42	910.45					609.00	
Space assessment	900.00	900.00	900.00	800.00	1,500.00					600.00	
Training expense	306.56	306.56	306.56	489.04	489.04					230.00	
Taxes & insurance	152.42	152.42	152.42	49.37	152.42					102.00	
Total fixed	6,145.62	6,145.62	6,145.62	2,888.89	6,362.64					4,130.00	
Variable:											
Operator wages	15,168.00	16,042.80	32,085.60	16,042.80	48,128.40					20,053.00	
Supply costs	5.76	5.76	5.76	1,815.36	10,301.76	(1,160.16)			(8,741.76)	1,120.00	
Maintenance and repair	187.01	187.01	187.01	59.23	161.64					165.00	
Calibration tests	125.00	125.00	125.00	0	0					400.00	
Utilities	163.80	163.80	163.80	452.71	4,012.32					76.00	
Total variable	15,649.57	16,524.37	32,567.17	18,370.10	62,604.12	(17,714.90)			(61,044.12)	21,814.00	
Total	21,795.19	22,669.99	38,712.79	21,258.99	68,966.76	(20,603.79)			(67,406.76)	25,944.00	
Per sample cost	6.98	0.73	0.37	6.81	2.21	(6.60)			(2.16)	0.83	

1/ Annual capacity based on 260 operating days. Twelve samples per day equal 3,120 samples annually; 120 samples per day. 31,200: and 400 samples per day, 104,000.

2/() = estimated costs of operations which recondense and reuse the solvent.

Table 8--Estimated supply costs for SE and NIR units 1/

Item	Cost	Solvent Extraction			Near-Infrared	
					Reflectance	
		12 unit cost per sample	120 unit cost per sample	120 samples per day cost per sample		
		<u>Dollars</u>				
Petroleum ether 2/	\$28.54 for 5 gals	\$0.32 (\$0.21)	\$0.07 (\$0.05)	--		
Super Cel H-333	\$13.89 for 3 kg	\$0.23	\$0.23	--		
Filter Paper	\$1.25 for 100	\$0.03	\$0.03	--		
	Total cost per sample	\$0.58 (\$0.47)	\$0.33 (\$0.31)			
Calcium carbonate	\$1.00 per lb.	--	--	\$0.07		

1/ Drierite desiccant cost is not included because it is a renewable item. The estimated cost for the desiccant would be \$5.76 for 2 lbs.

2/ One-third of ether cost could be saved by recondensing the ether instead of venting it. Estimate shown in () is cost when recondensing is used.

-- = not applicable.